IOSR Journal of Engineering (IOSRJEN) **www.iosrjen.org**
ISSN (e): 2250-3021, ISSN (p): 2278-8719
Vol. 09, Issue 7 (July. 2019), ||S (I) || PP 27-33

Design a household solar system for both space heating and domestic hot water for Hanoi-Vietnam

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Abstract: Solar energy has been used for water and space heating. Such thermal systems are used worldwide. In Vietnam, solar thermal systems to provide domestic hot water are widely used in major cities, however, similar system but with space heating function is rarely used. Solar combine system has several components. Functions of two main components are to collect solar energy from the sun and to store the collected energy for later use. The weather data are important to any implementation of solar thermal system because how much energy a system can collect from the sun is strongly related to the weather of the installed location. The design of a typical tube house for a family of four is considered to install solar combine system (for both domestic hot water and space heating). The amount of required energy for both functions is calculated then compared with the estimated solar energy collected at the site to determine whether or not an additional source of energy (gas, oil or electricity) is needed. The results are validated with computer software to see if the manual calculation is correct.

Keywords: Solar energy, Space heating, Domestic hot water (DHW), Solar thermal system

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Date of Submission: 03-07-2019 Date of acceptance: 18-07-2019

I. INTRODUCTION

Solar combine systems use heat from solar thermal collectors to provide space heating in winter and domestic hot water (DHW) all year round. (An auxiliary heat, additional boiler, is used as a back-up of the solar energy). The heating system intensifies the sun's power to heat water or air that is then used to heat the building. Specifically, solar water heating for domestic use means simply converting solar energy into thermal to increase water temperature to appropriate levels.

Vietnam is considered a nation with high solar potential. Solar energy intensity on the average is $5kWh/m^2$. The intensity is slightly lower in the North. The intensity is about $4kWh/m^2$ recorded at the area around Hanoi. This is because of the cloudy days (in winter and spring) and the drizzle days.Although recognized with huge potential, solar heat is used mostly at small scale in Vietnam. Due to changes in government's incentives, cheaper initial cost and longer system's life-time, high electricity price, Solar heating water has been applied at both the household and industrial levels.

However, there is little heard of a hybrid system of solar space heating and DHW in Vietnam. This can be understood using three factors pointed out by the International Renewable Energy Agency (IRENA): Technical, performance and cost, barrier and potential. The technology for solar thermal system is relatively simple technology and readily available. Many studies have been done by the IRENA, the International Energy Agency (IEA) to define the technical requirements of a solar thermal system. So it is highly possible and available for households and businesses in Vietnam to utilize the heat from the sun for heating purposes. Key challenge is the more complex process and associated costs of integrating solar thermal systems into existing housing. Therefore, probably the main factor hindered the utilization of solar heating system in Vietnam is from the "Performance and cost" factor. The high initial cost, the maintenance cost make up a significant amount. Even though, in a long term, this huge investment is justified however for a country with low income such as Vietnam, this is a drawback from users‟ point of view. Another cost factor is the price of alternatives. At the moment, it is cheaper to utilize heating in winter by electrical or oil heaters, air conditioners or primitively by burning wood, straw. Finally, there is a lack of public awareness and knowledge in Vietnam about solar thermal technology and the application options. Government and policy makers need to play the leading role in raising public recognition and acceptance which are necessary prerequisites for the diffusion of solar thermal heating technology in residential and public buildings.

II. MATERIAL AND METHOD

2.1 Basic componentsfor a solar thermal system

Solar water heaters and solar space heaters are made up of solar collectors, and all systems have some kind of storage. Active systems also have circulating pumps and controls; passive systems work without this added equipment. Three types of solar collectors are used for residential applications: flat-plate, integral collector-storage (ICS), and evacuated-tube collectors.

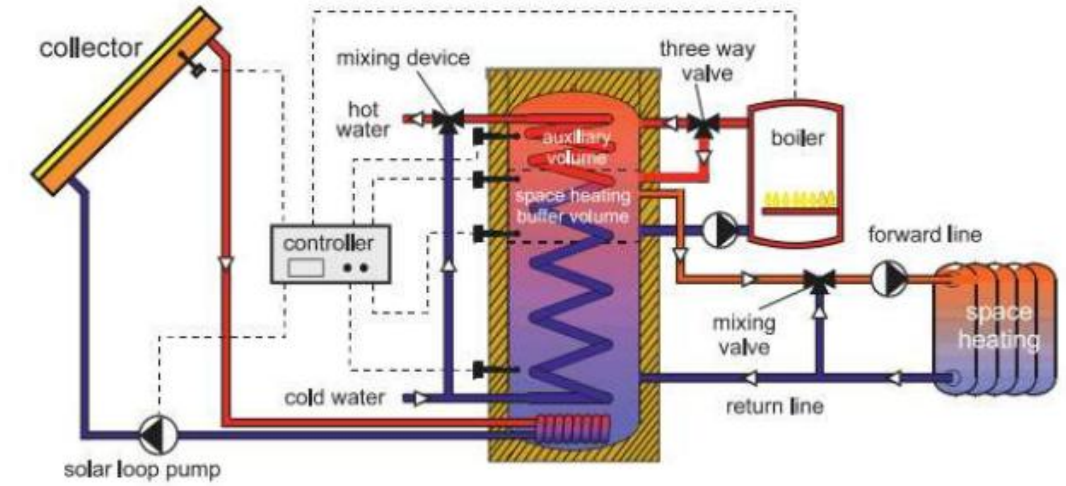

Fig.1. Typical schema of a solar heating combisystem (Adapted from IRENA)

2.2 Collection of weather data (monthly values) for Hanoi

2.2.1 Location

Hanoi has a warm temperate climate with dry winters and hot summers. The area is covered by croplands (91%), grasslands (4%), and lakes and rivers (3%).

2.2.2 Calendar

The summer and winter solstices and the spring and fall equinoxes mark the passing of the seasons. They fall on nearly the same day each year, with differences of a day or two depending on the year. In 2018 they occurred on:

Spring Equinox	Monday, 4 February 2018
Summer Solstice	Thursday, 21 June 2018
Autumn Equinox	Tuesday, 7 August 2018
Winter Solstice	Wednesday, 7November 2018

2.2.3 Temperature

The hottest day of2018 was July, with a high temperature of 39°C. For reference, on that day the average high temperature is 33°C and the high temperature exceeds 38°C only one day in ten. The hottest month of 2014 was June with an average daily high temperature of 34°C.

Relative to the average, the hottest day was February 20°C. The high temperature that day was 29°C, compared to the average of 21°C, a difference of 8°C. In relative terms the warmest month was January, with an average high temperature of 28°C, compared to a typical value of 20°C.

The longest warm spell was from January 18 to February 9, constituting 23 consecutive days with warmer than average high temperatures. The month of September had the largest fraction of warmer than average days with 80% days with higher than average high temperatures.

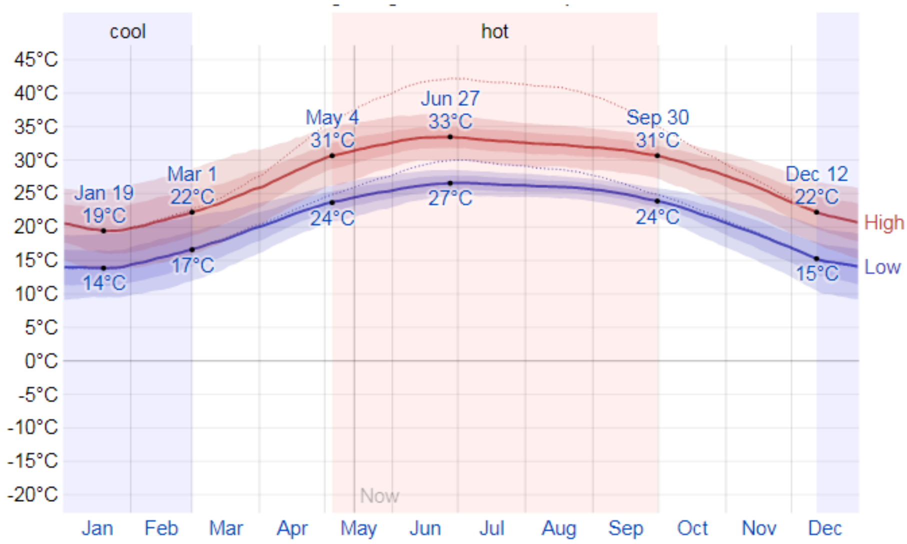

Fig.2 Average Daily Temperature of Hanoi

The daily low (blue) and high (red) temperature during 2018 with the area between them shaded gray and superimposed over the corresponding averages (thick lines), and with percentile bands (inner band from 25th to 75th percentile, outer band from 10th to 90th percentile). The bar at the top of the graph is red where both the daily high and low are above average, blue where they are both below average and white otherwise.

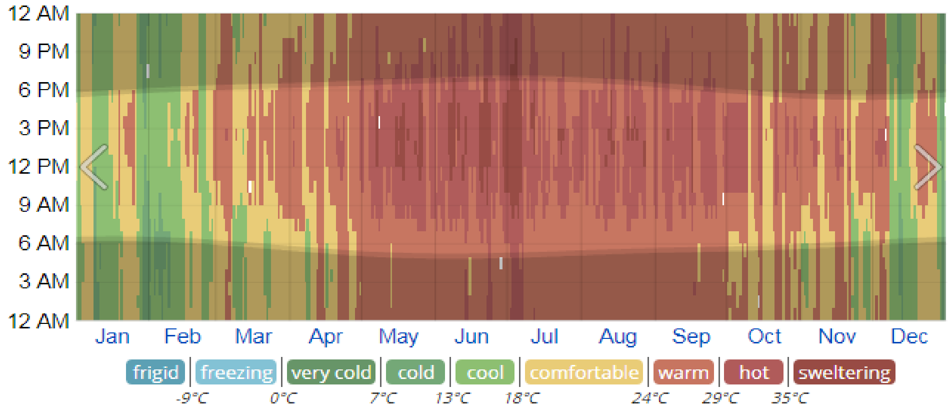

Fig.3 Hourly Temperature in 2018

The full year of hourly temperature reports with the days of the year on the horizontal and the hours of the day on the vertical. The hourly temperature measurement is color coded into meaningfultemperature bands: frigid is purple (below -9°C), freezing is blue (-9°C to 0°C), cold is dark green(0°C to 10°C), cool is light green (10°C to 18°C), comfortable is yellow (18°C to24°C), warm is lightred (24°C to 29°C), hot is medium red (29°C to 35°C), sweltering is dark red (above 35°C), andmissing data is pink.

2.3Definition of energy load

2.3.1 Heat requirement for DHW

A household in Hanoi has the following characteristics of water consumption:

- Number of occupants: 4 (parents and 2 kids)
- Average daily water usage: 200L (or 6000L per month)
- Average domestic hot water temperature: 60^{o}C

Month	Input water temperature (^{o}C)	Q per day (kWh)	Q per month (kWh)
Jan	10	11.6	360
Feb	10	11.6	325
Mar	13	11	341
Apr	17	9.9	297
May	21	9	279
Jun	21	9	270

Jul	23	8.6	267
Aug	23	8.6	267
Sep	22	8.8	264
Oct	20	9.3	288
Nov	14	10.7	321
Dec	11	11.4	353

Tab.1 DHW heat requirement

2.3.2 Heat requirement for space heating

A typical tube house in Hanoi is considered for the case study. Dimension of the house: 9m x 4m x 3.5m and it has 02 floors. There are a living room and a kitchen on the first floor and 2 bedrooms upstairs. This house is good candidate for solar heating because its structure minimizes heat loss. The house is considered fully insulated on the sides and the floor. Heat losses occur at the front and back walls, through windows and the roof. In this case study, the heat losses are heat transfer through the walls at the front (including wall, front-door, window), at the back (two windows) and through the roof. Assuming only the two bedrooms on the second floor need to be heated in the evening from 9PM – 7AM (10 hours). The energy required to heat up the room is considerably small compared to the heat losses. So this case study will calculate the heat losses to determine the required heat to keep the house at 21^{o}C (294K) constantly in the evening during winter's months (with outside temperature is the monthly average low temperature). Heat loss is calculated by: Calculate heat loss per "degree day". This is the loss per day with one degree difference between inside and outside temperature.

$$QlossWh = Area \times 1K \times U - value \times 10$$

(* U-value is the overall heat transfer coefficient.)

	Material	Qty	Area (m^2)	Total Area (m^2)	U-value (W/m^2K)	Heat Loss per degree day (Wh)
Windows	Vertical sealed double glazed	2	2.7	5.4	3.0	162
Ceiling	Concrete with insulation	1	36.0	36.0	0.9	324
Wall	Brick (25m)	1	22.6	22.6	2.0	452

Tab.2 Heat loss for entire year

(Based on the desired inside temperature: 21^{o}C (~ 294K))

Total energy required:

Month	For DHW	Space heating	Total
Jan	360	204	563
Feb	325	139	463
Mar	341	87	428
Apr	297	0	297
May	279	0	279
Jun	270	0	270
Jul	267	0	267
Aug	267	0	267
Sep	264	0	264
Oct	288	0	288
Nov	321	57	378
Dec	353	204	557

Tab.3 Total energy required

III. RESULTS

3.1 Calculate output from solar collector

In order to simplify the calculation, the following assumption is made:

- Circulated liquids are used to carry collected energy to storage and load.
- The solar collector direction: facing directly south.
- The collector is set at a 54° angle - (for best winter performance).

Computing collector output is a sophisticated task, normal it is done by computers. For small scale systems such as the one in this case system, however, a simplified calculation method adapted from "CDA Sun-Chart Hand Calculations" (by Copper Development Association Inc.) can provide results closely matched those done by computer analysis. The calculation is best described in a tabular form.

Month	Collect or Heat gain factor	Collect or Heat loss factor	Average Daytime Air Temp (°C)	Average Solar Insolation (kWh/m² per day)	Average Water Input Temp (°C)	Collector Inlet Temp (°C) $G = E - 27$	$H = G - C$	$J = B/A \times 2H$	$K = J/(D \times 317)$	Obtained from Figure "Collectable Energy Graph"	Total energy collected (kWh/m² per day) = $D \times L$
Jan	0.7	0.65	20	2.78	10	37	61	114	0.13	0.39	1.08
Feb	0.7	0.65	20	3.02	10	37	61	205	0.21	0.28	0.85
Mar	0.7	0.65	25	3.61	13	39	58	193	0.17	0.32	1.16
Apr	0.7	0.65	30	3.68	17	44	57	191	0.16	0.34	1.25
May	0.7	0.65	35	3.91	21	48	55	184	0.15	0.35	1.37
Jun	0.7	0.65	36	4.31	21	48	53	176	0.13	0.39	1.68
Jul	0.7	0.65	36	4.2	23	49	56	186	0.14	0.37	1.55
Aug	0.7	0.65	36	3.99	23	49	56	186	0.15	0.35	1.40
Sep	0.7	0.65	35	4.21	22	49	57	191	0.14	0.37	1.56
Oct	0.7	0.65	31	4.04	20	47	60	200	0.16	0.34	1.37
Nov	0.7	0.65	26	4.02	14	41	57	192	0.15	0.35	1.41
Dec	0.7	0.65	22	3.6	11	38	61	204	0.18	0.31	1.12

Tab.4 The calculated solar collector production

3.2Discussing

3.2.1 Comparing the total energy collected and the required energy

The total energy collected depends on the collector area. For this case study, considered three different collector's areas: 18m², 9m², 4.5m² (a half, a quarter and one-eighth of the roof area respectively).

Month	Total energy collected (kWh/m² per day)	Total energy collected (kWh/m² per month)	Total energy collected with collector Area (kWh per month)			Total energy required
			18m²	9m²	6m²	
Jan	1.08	33.61	604.98	302.49	201.66	563.15
Feb	0.85	23.68	426.18	213.09	142.06	463.41
Mar	1.16	35.81	644.60	322.30	214.87	428.23
Apr	1.25	37.54	675.65	337.82	225.22	297.00
May	1.37	42.42	763.62	381.81	254.54	279.00
Jun	1.68	50.43	907.69	453.84	302.56	270.00
Jul	1.55	48.17	867.13	433.57	289.04	266.60
Aug	1.40	43.29	779.25	389.62	259.75	266.60
Sep	1.56	46.73	841.16	420.58	280.39	264.00
Oct	1.37	42.58	766.47	383.23	255.49	288.30
Nov	1.41	42.21	759.78	379.89	253.26	378.25
Dec	1.12	34.60	622.73	311.36	207.58	556.95
Total			**8659.24**	**4329.62**	**2886.41**	**4321.49**
%			200.38%	100.19%	66.79%	100.00%

Tab.5 The annual heat requirement and solar collector productions

In a combined space and water heating system, sizing of the solar production is targeted so that the collector will produced about 60-70% the annual heat requirements.As shown in table 5, a preliminary estimate of 9m2 solar collector provides 66.79% of the annual heat requirements.

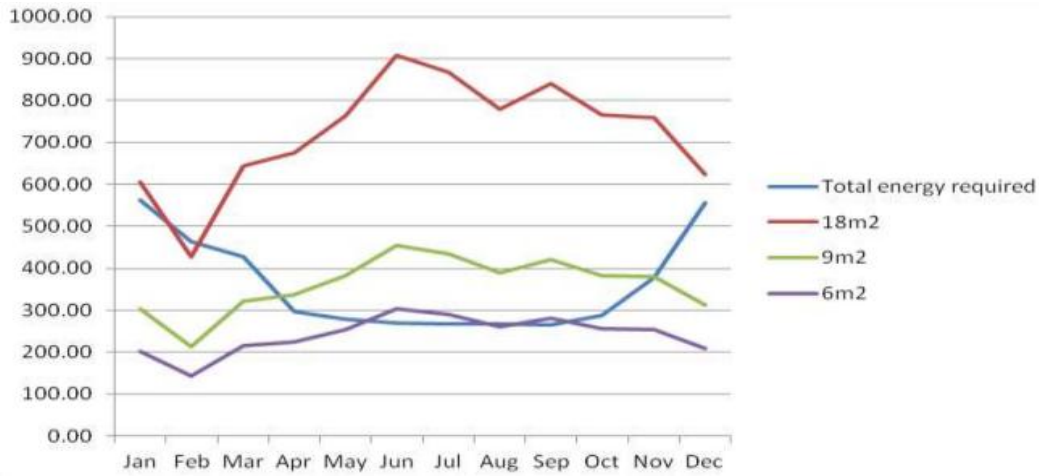

Fig.4 Annual heat requirement and solar collector productions

3.2.2 Additional heat required

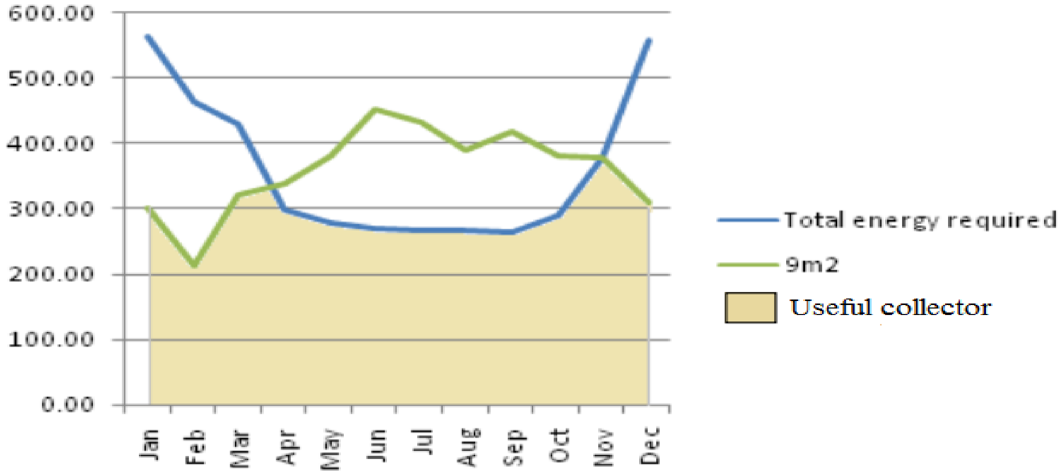

Fig.5 Annual heat requirement and 9m^{2}solar collector productions

Figure 5 shows the total useful heat produced by the solar collector, which is less than the total heat required for the combine space and water heating. Obviously, an auxiliary source of heat is required such as gas, oil or electric heaters. . Although, the solar collector does not produce all the heat required for the combined heating system, it helps reduce the dependence on traditional sources of energy, save the on energy bills and produce less pollution.

IV. CONCLUSION

Solar thermal systems particularly make sense for three categories of countries: 1) countries that rely on gas or oil imports to cover their heating needs; 2) countries with growing economies where the use of electric boilers for water heating is straining the expansion of the electricity system to satisfy electricity demand: and 3) countries with high cooling demand during sunshine hours. Situation of Vietnam Northern Vietnamese has rarely installed an automatic space heating system. The cost of such systems is often too expensive for general public. The benefits of a space heating system can hardly justify the cost to install it. On the other hand, there are Solar combine systems more and more people install solar hot water systems because of the long-term saving on cost of energy and the government subsidizing policy on solar hot water. So in order to promote the use of a combined solar thermal system of DHW and space heating, the cost of such system must be lower and probably, it needs a government incentive program similar to the one with solar hot water system.

ACKNOWLEDGEMENTS

This paper was supported by the Institute of Energy Science, Vietnam Academy of Science and Technology, and The University of Science and Technology of Hanoi. We would like to extend our gratitude to our colleagues and scientists for their excellent comments on this article and hope to continue to receive comments from these specialized experts in future articles.

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CUThiThanh Huyen . "Design a household solar system for both space heating and domestic hot water for Hanoi-Vietnam." IOSR Journal of Engineering (IOSRJEN), vol. 09, no. 07, 2019, pp. 27-33